EXPLORATION OF METHODS TO ENHANCE LFT&E AND TOTAL SHIP SURVIVABILITY IN LPD-17

Charles N. Calvano, Professor
Department of Mechanical Engineering
Robert Harney, Senior Lecturer
Department of Physics
Sponsor: Commander Operation Test and Evaluation Force

OBJECTIVE: COMOPTEVFOR will conduct an operational assessment of LPD-17 during the detail design stage, and innovative attempt to more effectively and efficiently ensure the delivery of a ship, which meets all fleet needs. COMOPTEVFOR will assess the value of this innovative approach to assessing the potential operational effectiveness of the ship. To support this effort, COMOPTEVFOR is assembling a team of "subject matter experts" to assist in the experiment and has requested the investigators to provide evaluation in the areas of live fires test and evaluation and total ship survivability.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ship and Watercraft

KEYWORDS: Live Fire Test and Evaluation, Ship Survivability, Ship Design, Operational Assessment

DESIGN AND ANALYSIS OF HINGE CONNECTOR FOR SLICE-TRAILER TOWING

Charles N. Calvano, Professor
Fotis A. Papoulias, Associate Professor
Joshua H. Gordis, Associate Professor
Department of Mechanical Engineering
Sponsor: Office of Naval Research

OBJECTIVE: The objective of this project was to support the Office of Naval Research in further development of the novel SLICE hull form with a trailer hull.

SUMMARY: The focus of this project was on a hinge connection between the "tractor" and "trailer" SLICE vessels. This provides a number of technical challenges in high-speed high sea state ocean towing systems that have not been studied in the past. The investigators reviewed industry designs, participated in discussions of the work with industry and ONR, analyzed design alternatives and commented on them, and suggested modifications or alternatives as part of the hinge design Integrated Product Team (IPT). A detailed study of the maneuvering and seakeeping qualities of the two interconnected bodies was initiated focusing primarily on hinge load prediction in a given sea. Current efforts are focusing on ways to mitigate motions and/or loads during high-proximity towing.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ships and Watercraft

KEYWORDS: Towing, Seakeeping

IMPROVEMENT OF DELIVERY ACCURACY METHODOLOGY

Morris Driels, Professor
Department of Mechanical Engineering
Sponsor: United States Army Aeronautical Systems Center

OBJECTIVE: To review delivery accuracy methodologies applicable to GPS/INS Weapons Systems, including dispenser weapons. To review AGM65 (MAVERICK) field trial data and analyze for consistent DA parameters for inclusion into JAWS.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications

KEYWORDS: Weapon Effects, Delivery Accuracy, Weaponeering

JMEM AIR TO SURFACE TASKS 3, 8, 16

Morris Driels, Professor
Department of Mechanical Engineering
Sponsors: Joint Technical Coordinating Group and Naval Postgraduate School

OBJECTIVE: To improve delivery accuracy methodology and to develop a real time DA capability.

SUMMARY: The first part of the project was to develop a spreadsheet that would compute delivery accuracy of unguided weapons. This was accomplished with the assistance of LT T. Smith. The second part was to begin translating this methodology into a C++ environment capable of being integrated directly into JAWS. The third task related to the analysis of accuracy for the AGM-65 Maverick missile, and the calculation of accuracy parameters for the JAWS program.

THESIS DIRECTED:

Smith, T., "Real Time Computation of the Delivery Accuracy for Air Launched Unguided Weapons," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Bombing Accuracy, Weaponeering

IMPLEMENTATION OF THE DELPHI TARGET ACQUISITION MODEL

Morris Driels, Professor
Department of Mechanical Engineering
Sponsors: United States Army TRADOC Analysis Command-Monterey

OBJECTIVE: To further refine earlier work on the development of a visual performance model based on a public domain version of the BAe ORACLE model.

SUMMARY: This small carry-over project from FY99 was to document the results and provide a user manual for the sponsor.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Software, Target Acquisition, Combat Models

BOUNDARY ENHANCEMENTS TO THE ACQUIRE MODEL

Morris Driels, Professor
Department of Mechanical Engineering
Sponsors: United States Army TRADOC Analysis Command-Monterey

OBJECTIVE: To adapt the US Army ACQUIRE model to include the detectability of edges.

SUMMARY: This was a collaborative project with UC Berkeley, where Professor Stark's team had an experimental facility to allow the measurement of visual targets by human subjects. The NPS contribution was to specify the type and scope of the tests UCB would do, and to interpret the results in a military context. Work is continuing on the formulation of a model to embody the results.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Human Vision, Search, Target Detection

COMPUTING UNGUIDED DELIVERY ACCURACIES IN REAL TIME

Morris Driels, Professor
Department of Mechanical Engineering
Sponsor: Aeronautical Systems Command

OBJECTIVE: The project will develop the methodologies for computing delivery accuracy data for unguided weapons in real time rather than off-line, and will document the modes and mechanizations applicable for the aircraft studied.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications

KEYWORDS: Weapon Accuracy, Weaponeering

INFRARED CONTRAST SIGNATURE MODELING

Morris Driels, Professor
Department of Mechanical Engineering
Sponsors: United States Army TRADOC Analysis Command-Monterey

OBJECTIVE: To develop initial standards for the U. S. Army modeling and simulation effort in the area of IR target detection methodologies. The effort will be part of a combined proposal from NPS, IDA and NVESD.

SUMMARY: A technical description of the Electro-Optical Tactical Decision Aid (EOTDA) was written in the form of U. S. Army standard and submitted to the ACQUIRE Standards Committee. This is now becoming the Standard for U. S. Army model of IR signatures.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Software, Target Acquisition, Combat Models

INTERFACIAL SLIDING IN MULTI-COMPONENT SYSTEMS

Indranath Dutta, Associate Professor
Department of Mechanical Engineering
Sponsor: National Science Foundation

OBJECTIVE: To investigate the mechanisms of creep at interfaces of dissimilar materials.

SUMMARY: The goal of this project is to develop a phenomenological understanding of the mechanisms operative during sliding of interfaces at high temperatures. A combination of experimental and analytical means are being utilized to investigate the kinetics of interfacial sliding and its effect on thin film systems.

PUBLICATIONS:

Dutta, I., "Role of Interfacial and Matrix Creep During Thermal Cycling of Continuous Fiber Reinforced Metal-Matrix Composites," *Acta Materialia*, 48, 2000, pp. 1055-1074.

Chen, M.W. and Dutta, I., "Atomic Force Microscopy Study of Plastic Deformation and Interfacial Sliding in Al Thin Film: Si Substrate Systems due to Thermal Cycling," *Applied Physics Letters*, 77, 2000, pp. 4298-4300.

THESIS DIRECTED:

Peterson, K., "An Experimental Set-up for Studying the Creep Behavior of Planar Al-Si Interfaces," Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEY WORDS: Composite, Multi-layers, Thin Films, Creep, Interfacial Sliding

PROCESSING AND FRACTURE OF PARTICULATE REINFORCED METAL-MATRIX COMPOSITES

Indranath Dutta, Associate Professor
Department of Mechanical Engineering
Sponsors: Air Force Research Laboratory

OBJECTIVE: To correlate processing, microstructure and fracture properties in particulate reinforced aluminum (PRA) composites.

SUMMARY: The purpose of this project is to investigate microstructural development during processing of PRA, specifically with respect to the evolution of particulate distribution and matrix grain and precipitate structure, and to evaluate the impact of fracture properties and mechanisms. The eventual goal is to design the material microstructure in such a way so as to result in substantially improved fracture toughness, while retaining the stiffness and strength advantage of PRA relative to unreinforced aluminum alloys.

PUBLICATION:

Nagarajan, R. and Dutta, I., "A Novel Approach for Optimizing the Fracture Toughness of Precipitation Hardenable Al-SiCp Composites," to appear in *Metallurgical and Materials Transactions A,* 2001 (accepted in October 2000).

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEY WORDS: Composites, Fracture, Matrix Microstructure

THERMO-MECHANICAL BEHAVIOR OF SOLDER JOINTS FOR ELECTRONIC PACKING

Indranath Dutta, Associate Professor
Ashok Gopinath, Associate Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: To obtain a mechanistic understanding of the relationship between micro structural coarsening and applied constraints during thermo-mechanical cycling of solder joints.

SUMMARY: Flip Chip and Ball Grid Array solder joints in electronic packaging applications are subjected to large imposed strains and temperature variations during service conditions. During cycling, the microstructure coarsens, plastic strains localize, and the solder joint eventually fails by low-cycle fatigue induced by permanent creep deformation. The purpose of this project is to understand the dependence of micro-structural coarsening on the plastic strain state in a solder joint during thermomechanical cycling.

PUBLICATION:

Dutta, I., Gopinath, A., and Marshall, C.,"Effect of Underfill Constraints on Thermal Cycling Behavior of Flip Chip Solder Joints," presented at the 2000 TMS Fall Meeting and Exhibition, St. Louis, MI, 4-8 October 2000.

THESIS DIRECTED:

Marshall, C., "Constraint Effects During Thermo-Mechanical Cycling of Flip Chip Solder Joints Under Shear," Masters Thesis, Naval Postgraduate School, December 2000.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEY WORDS: Electronic Packaging, Solder, Thermal Cycling, Deformation

EVALUATION OF THE EFFECTS OF WATER DEPTH ON WELD METAL MICROSTRUCTURE WHEN USING NICKEL-BASED AUSTENITIC ELECTRODES FOR THE UNDERWATER WET WELDING OF HIGH-STRENGTH FERRITIC STEELS

Alan G. Fox, Professor
Department of Mechanical Engineering
Sponsor: Naval Sea Systems Command

OBJECTIVE: To evaluate the use of Ni-based austenitic electrodes for the underwater wet welding of high strength ferritic steels

SUMMARY: Previous work in collaboration with NSWC on the underwater wet welding of high strength ferritic steels indicated that the use of ferritic electrodes often led to hydrogen-assisted underbead cracking, especially at low water temperatures. In the present work, in order to try and alleviate this cracking, more ductile Ni-based austenitic electrodes were used. The use of austenitic electrodes proved highly successful with no underbead cracking encountered in any of the weldments. Unfortunately, at water depths greater than about 30 feet, especially when welding in the overhead position, significant amounts of porosity were encountered which occasionally put the weldments out of specification. Further work is needed to understand and provide a means for the elimination of this porosity.

THESIS DIRECTED:

Sheakley B.J., "Effect of Water Depth on the Underwater Wet Welding of Ferritic Steels Using Austenitic Ni-based Alloy Electrodes," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEYWORDS: Underwater Wet Welding, Ferritic Steels, Ni-based Electrodes

COMPOSITIONAL AND MICROSTRUCTURAL ANALYSIS OF ADVANCED ULTRA-LOW CARBON FERRITIC STEEL WELDMENTS-SEGREGATION OF CARBON IN THE WELD METAL

Alan G. Fox, Professor
E. Sarath K. Menon, Research Associate Professor
Department of Mechanical Engineering
Sponsor: Naval Research Laboratory

OBJECTIVE: To evaluate the segregation of carbon in weld metal deposited with ultra-low-carbon (ULC)-alloy steel consumables

SUMMARY: Previous work in collaboration with NRL on this topic has shown how the segregation of carbon between the microconstituents, martensite, ferrite and retained austenite in ultra-low carbon steel weld metals (containing about 0.03 wt.% C) could be quantified by the use of parallel electron energy loss spectroscopy (PEELS) in the transmission electron microscope (see the publication below). These studies have more recently been extended to include weld metals deposited with the most recently developed Navy ULC steel weld consumable electrodes and segregation of carbon in the microconstituents present in these has been evaluated. These studies are still ongoing.

PUBLICATION:

Menon, E.S.K. and Fox, A.G, "Detection, Distribution and Quantification of Carbon in Steel Microstrucures by Parallel Electron Energy Loss Spectroscopy," accepted for publication in *Microscopy and Microanalysis.*

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEYWORDS: Ultra-Low Carbon Steel Welding Consumables, Analysis of Carbon in Steels by Parallel Electron Energy Loss Spectroscopy

MICROSTRUCTURAL STUDIES OF ULTRA-LOW CARBON STEEL WELD METAL

Alan G. Fox, Professor
Department of Mechanical Engineering
Sponsor: Naval Surface Warfare Center-Carderock

OBJECTIVE: To evaluate the microstructures that develops in Navy ultra-low carbon steel weld metals with particular emphasis on the role of non-metallic inclusions.

SUMMARY: Previous work in collaboration with NSWC on this topic has shown how non-metallic inclusions have a significant effect on the microstructure and mechanical properties (strength and toughness) of ultra-low carbon (ULC) steel weld metal deposited by the gas-metal-arc welding process. In this work we studied the effect of non-metallic inclusions on the weld metal microstructure and strength and toughness as a function of welding parameters and weld metal composition for a series of ULC samples. These results indicated that Military Specifications for 100 ksi yield strength weld metal could be met with ULC consumable electrodes provided the weld metal composition was carefully controlled.

THESIS DIRECTED:

Van Slyke, J.J., "Factors Affecting the Strength and Toughness of Ultra-Low Carbon Steel Weld Metal," Masters Thesis, Naval Postgraduate School, January 2000.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEYWORDS: Ultra-Low Carbon Steel Welding Consumables, Non-Metallic Inclusions

THERMOACOUSTIC EFFECTS AT A SOLID-FLUID BOUNDARY: THE ROLE OF A SECOND ORDER THERMAL EXPANSION COEFFICIENT

Ashok Gopinath, Associate Professor
Department of Mechanical Engineering
Sponsor: National Aeronautics and Space Administration-Lewis

OBJECTIVE: To conduct fundamental material and transport studies on thermo-acoustic phenomena in microgravity with future application to thermoacoustic based energy processes aboard the Space Station.

SUMMARY: An analytical study was conducted to show that small particles in a strong acoustic field can be heated by very substantial heat fluxes. The study provides a theoretical basis for the development of a novel technique that could find use in the simultaneous levitation and heating of particles by acoustic means for "ultra-clean" materials processing applications. Results from an experimental study on the development of empirical correlations of use in the design of heat exchangers for thermoacoustic engines was also reported.

PUBLICATIONS:

Gopinath, A. and Harder, D. R., "An Experimental Study of Heat Transfer from a Cylinder in Low-Amplitude Zero-Mean Oscillatory Flows," *International Journal of Heat & Mass Transfer*, Vol. 43, No. 4, pp. 505-520, February 2000.

Gopinath, A., "Thermoacoustic Streaming on a Sphere,'' *Proceedings of the Royal Society (series A), London*, Vol. 456, No. 2002, pp. 2419-2439, October 2000.

Gopinath, A., "Thermoacoustic Streaming on a Cylinder,'' *Proceedings of the Symposium on Energy Engineering*, Vol. 3, pp. 1170-1177, Ping Cheng, ed., Hong Kong, January 2000.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures, Modeling and Simulation, Other (Basic Science)

KEYWORDS: Thermoacoustics, Acoustic Streaming, Acoustic Levitation, Thermo-Physical Property Measurement, Thermodynamic Moduli, Oscillatory Flows, Asymptotic Techniques.

ACOUSTIC STREAMING IN MICROGRAVITY: FLOW STABILITY AND HEAT TRANSFER ENHANCEMENT

Ashok Gopinath, Associate Professor
Department of Mechanical Engineering
Sponsor: National Aeronautics and Space Administration-Jet Propulsion Laboratory

OBJECTIVE: To conduct fundamental material and transport studies on the role of acoustic streaming in enhancing transport rates in microgravity with application to materials processing.

SUMMARY: The problem of steady streaming on an object in an acoustic field was generalized to provide new results on the effect of object location, and fluid compressibility. The results show that dramatic changes are possible in the flow, and are a likely explanation for the intermittent and fleeting flow patterns that have been observed in experimental studies on acoustic levitation.

PUBLICATION:

Gopinath, A. and Trinh, E. H., "Compressibility Effects on Steady Streaming from a Non-Compact Rigid Sphere," *Journal of the Acoustical Society of America*, Vol. 108, No. 4, pp. 1514-1520, October 2000.

THESIS DIRECTED:

Lowe, G., "Acoustically Forced Heat Transfer from a Tube Bank," Master's Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Other (Energy Systems)

KEYWORDS: Acoustic Streaming, Heat Transport, Asymptotic Techniques

EXPERIMENTAL STUDIES OF LIQUIDS IN TENSION

Ashok Gopinath, Associate Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: To study the tensile load bearing capabilities of thin trapped liquid layers.

SUMMARY: An experimental study was initiated to study the behavior of thin trapped liquid layers subject to separating tensile forces. Both quantitative (force-displacement) data and qualitative (visual) data were gathered in the course of a second student thesis. The data support the basic model of a viscous dominated resistance to the separation of the liquid layers.

THESIS DIRECTED:

Rehkop, C. H., "An Experimental Study of Liquids in Tension," Master's Thesis, Naval Postgraduate School, March 2000.

PRESENTATIONS:

Gopinath, A. and Isik, S., "An Experimental Study of Liquids in Tension," Interfaces for the 21st Century – New Research Directions in Fluid Mechanics & Materials Science, Monterey, CA, August 1999.

Gopinath, A, "The Role of Viscous Fingering in the Separation Mechanics of Thin Interfacial Liquid Layers," Gallery of Fluid Motion, 52nd American Physical Society Meeting, New Orleans, LA, November 1999.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEYWORDS: Surface Tension, Viscous Fingering, Cavitation, Lubrication

DESIGN OF LAB-SCALE MODEL TEST OF ISOLATION FOR RORO RAMP

J. H. Gordis, Associate Professor
F. A. Papoulias, Associate Professor
Sponsor: Naval Surface Warfare Center-Carderock

OBJECTIVE: The objective of this project was to perform frequency response analysis of the DTMB runs 1-503 and NRL runs 1-217 of the T-ACS seakeeping experiments.

SUMMARY: In Sea State 3 and above, the stern ramp of the Cape T ship is vulnerable to an overstress condition when off-loading vehicles. Therefore, there exists a need to design motion-compensation devices ("isolation") which when placed between the end of the ramp and the barge, precludes the possibility of a ramp overstress condition. Parallel to analytical studies conducted under separate funding, there is a need to establish an accurate and cost-efficient experimental set-up in order to validate the theoretical models. This need is addressed in this work. A basic experimental configuration has been designed and built. Actual testing and data analysis is set to begin during the month of February. Further data analysis and conclusions along with recommendations of the most promising designs will be reported during this year.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Frequency Response, Seakeeping, Vibration Isolation, Testing and Evaluation

REDUCING RAMP STRESS LEVELS VIA SEMI-ACTIVE DAMPING

J. H. Gordis, Associate Professor
F. A. Papoulias, Associate Professor
Sponsor: Naval Surface Warfare Center-Carderock

OBJECTIVE: The current ramp design used in roll-on roll-off operations has been determined to be structurally inadequate in sea state 3. The overall objective of this continuing project is to determine the isolation properties that are required in order to reduce ramp stress levels below the allowable for worst-case loading.

SUMMARY: A mathematical model describing the fundamental physics of a ship/ramp/barge system, including a passive isolator, was developed. The model properly accounts for hydrodynamic proximity effects and structural coupling between the bodies. Preliminary parametric studies, utilizing a standard second order model for the frequency response properties of the connecting body, of the response amplitude operator of the ramp motion were performed for varying wave directions and isolator stiffness and damping. These were utilized for random wave analysis in standard fully developed seas. The results indicated that rational selection of isolator properties could result in significant reduction of motions and stress levels in the connecting ramp. Current efforts include incorporation of actual FEM results coupled with the existing hydrodynamic prediction models.

PUBLICATION:

Gordis, J. H., Papoulias, F., and Leban, F., "Validation of Frequency Response Synthesis for Large-Scale Structural Isolation Design," *Proceedings, 71st Shock and Vibration Symposium,* Arlington, VA, 6-9 November 2000.

THESIS DIRECTED:

Konstantinou, D. S., "Random Wave Analysis of Ship/Ramp/Barge Response," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Frequency Response, Seakeeping, RORO Operations, Vibration Isolation

EFFICIENT NONLINEAR TRANSIENT DYNAMIC ANALYSIS FOR STRUCTURAL OPTIMIZATION USING AN EXACT INTEGRAL EQUATION FORMULATION

Joshua H. Gordis, Associate Professor
Department of Mechanical Engineering
Beny Neta, Professor
Department of Mathematics
Sponsor: National Science Foundation

OBJECTIVE: This project is concerned with the theoretical development and computational implementation of a time domain theory for locally nonlinear transient structural synthesis. Application principally will be made to seismic isolation.

SUMMARY: This research concerns the continued development of a time domain theory for structural synthesis. This theory provides the previously unavailable capability of performing exact damped transient structural synthesis for systems with localized non-linear components with the order of the synthesis being independent of model size. The method is based on Volterra integral equations derived from the convolution integral, which describe substructure coupling and structural modification. Current results demonstrate an order of magnitude reduction in compute times as compared with widely used commercial finite element analysis packages. The use of the formulation for the optimal design of seismic isolation is

under development. The algorithm has been extended to treat nonlinear memory-type elements (e.g. elastoplastic hysteretic).

PUBLICATION:

Gordis, J. and Neta, B., "An Adaptive Method for the Numerical Solution of Volterra Integral Equations," *Recent Advances in Applied and Theoretical Mathematics*, N. Mastorakis, ed., World Scientific and Engineering Society International Conference, Athens, Greece, 1-3 December 2000, pp. 1-8.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Structural Dynamics, Transient Response, Nonlinear Dynamics, Seismic Isolation

STUDIES IN INTELLIGENT CONTROL OF AUTONOMOUS VEHICLES

Anthony J. Healey, Professor
Department of Mechanical Engineering
Sponsor: Ford Motor Company

OBJECTIVE: This grant is in the support of research in the subject matter without restriction, and serves to aid the ongoing programs in the Center for Autonomous Underwater Vehicle Research.

SUMMARY: This project has supported the purchase of radio ethernet communications devices and radio modem connections between the ARIES robot and a shore based operator station. Also, it has supported the purchase of mobile laboratory equipment necessary to the deployment of ARIES in Monterey Bay.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ship and Watercraft

KEYWORDS: Autonomous Systems, Robotics, Vehicles, Navigation

HYDROTHERMAL VENT MAPPING WITH MULTIPLE AUTONOMOUS UNDERWATER VEHICLES

Anthony J. Healey, Professor
David. B. Marco, Mechanical Engineer
Department of Mechanical Engineering

OBJECTIVE: The Naval Postgraduate School (NPS) and the Institution Superior Technico, Lisbon (IST) have a long standing memorandum of agreement dating back to 1994 for the exchange of scientific ideas, visits of faculty and students, and to perform collaborative work. In the past we have collaborated on joint papers, the shared supervision of doctoral work, and a shared effort on the evaluation of AUV control system methodology and strategic level mission specifications using Petri net methods. This is a NICOP project aimed at developing the technology of multiple cooperating AUVs in a shallow water vent-mapping mission. The missions to be conducted in the AZORES off Terceira Island in 2001 will develop multi vehicle cooperative strategies and control using radio and acoustic communications. Results of both sonar and video images will be obtained in which the Portuguese vehicle - MARIUS and a surface catamaran (DELFIN) will perform broad area survey to identify vent clusters, while the NPS vehicle - ARIES will be used to reacquire vent cluster locations and perform local area searches with close in video data gathering.

The major goals of the mission are to demonstrate the use of multiple AUVs to map the shallow water areas of the Azores in the Joao de Castro Bank off Terceira. The waters are shallow (10 - 20 meters) around the peaks of the bank where large clusters of these vents are known to exist. Water depths in the crater go to 40 meters. The objectives include using multiple cooperating AUVs and the evaluation of methodologies employed for multi vehicle control, common control languages, and cooperative command and control. While there is a scientific need to study the vents with more detail than possible using divers and cameras,

this also presents a parallel to the minefield reconnaissance and mapping problem in very shallow water - so necessary to the US Navy.

The IST has been approved to conduct a mission in the Azores (the AZIMOV project) using cooperative behaviors between a surface catamaran vehicle (DELFIN) and an underwater vehicle (MARIUS). The project involves the French companies Thompson and ORCA, and personnel within the GESMA (French Navy), as well as faculty from IST. NPS will provide the cooperating underwater vehicle ARIES which has a video capability.

The approach for mapping these shallow water vent areas will be to employ a combination of low resolution sensors (sonar's) on one vehicle (Marius and / or Delphin) to detect the presence and general location of extensive clusters of vents, and to communicate the cluster location data information by acoustic and radio modems to the NPS ARIES AUV. The ARIES will have the capability to reaquire the vent area using its DGPS / Doppler / IMU navigational suite, and to conduct a survey of the local area with both a sector scanner sonar and a video camera. ARIES will provide geo-located video images of the vents, taken from a slow speed local search at constant altitude.

Since September 1999, we have been developing the capabilities of the ARIES vehicle, shown below at AUVFEST 99 in Gulfport, Mississippi, November 1999, [1] in which we have developed the propulsion system, the navigational system, and the C4I systems. The vehicle now runs in Monterey Bay in the very shallow waters and has been used to gather bathymetry data and video imagery of the bottom, including geo-locations superimposed on the images. The camera output is recorded to a DV recorder and played back after recovery. The vehicle is equipped with an acoustic ground locked Doppler Sonar, DGPS, compass, and a low cost inertial motion unit. Navigation accuracies have been improved through the use of an Extended Kalman Filter and reported in [2]. We are looking into radio video transmission for increased speed of data transfer. The ARIES and the Delphin vehicles are illustrated in the Figure1 and 2 below. The Delphin autonomous surface craft has been developed and field-tested this summer.

The vehicle is capable of 5 knots and can be driven to autonomous commands through its radio link, or interactively by 'joy stick' operator station, giving speed-heading commands. Navigation is accomplished using DGPS since the vehicle is always on the surface. Speed measurement and heading is taken from a Thompson acoustic ground locked Doppler sonar and a compass. The vehicle has been described at the IEEE 2000 Oceans meeting, [3, 4].

New technology being demonstrated include: (1) Multi vehicle cooperation via data sharing; (2) Shallow water target reacquisition and navigational accuracy; (3) Shallow water object mapping; and (4) Coordinated Mission Control.

PUBLICATIONS:

Marco, D. B. and Healey, A. J., "Current Developments in Underwater Vehicle Control and Navigation: The NPS ARIES AUV," *Proceedings of IEEE OCEANS 2000,* Providence, RI, September 2000.

Alves, J. et. al. "An Autonomous Surface Craft for Ocean Operations," *Proceedings of IEEE Oceans 2000,* Providence, RI, September 2000.

Pascoal, A., et. al., "Robotic Ocean Vehicles for Marine Science Applications: The European AZIMOV Project," *Proceedings of IEEE OCEANS 2000,* Providence, RI, September 2000.

Healey, A. J., "Optimal Fault Detection and Resolution During Maneuvering for AUVs," *Proceedings of MCMC 2000,* Aalborg University, Denmark, 23-25 August 2000.

Marco, D. B. and Healey, A. J., "Current Developments in Underwater Vehicle Control and Navigation: The NPS ARIES AUV," *Proceedings of IEEE OCEANS 2000,* Providence, RI, September 2000.

Riedel, J., "Shallow Water Stationkeeping of an Autonomous Underwater Vehicle: Experimental Results of a Disturbance Controller," *Proceedings of IEEE OCEANS 2000,* Providence, RI, September 2000.

Healey, A. J. and Kim, Y., "Control and Random Searching with Multiple Robots," accepted in *Proceedings of IEEE CDC2000,* Paper No. INV2303, Sydney, Australia, November 2000.

THESES DIRECTED:

Gibbons, A. S., "Optimal Fault Detection and Resolution During Maneuvering for Autonomous Underwater Vehicles," Masters Thesis, Naval Postgraduate School, March 2000.

Ludwig, P. M., "Formation Control for Multi-vehicle Robotic Minesweeping," Masters Thesis, Naval Postgraduate School, June 2000.

Allyne, J. "AUV Navigation with Range Only Measurement," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ship and Watercraft

KEYWORDS: AUV, Shallow Water Vent Mapping

TACTICAL DECISION AIDS FOR AUTONOMOUS UNDERWATER VEHICLES

Anthony J. Healey, Professor
Department of Mechanical Engineering
Sponsor: Office of Naval Research

OBJECTIVE: This work is aimed at developing Tactical Decision Aids for the use of AUVs. The primary focus is on gathering AUV data and building a common operating environment in which to view simulation results as well as near to real time actual results for mine counter measures work.

SUMMARY: Since the US Navy already uses an established Tactical Decision Aid (the MEDAL system), our approach is to supplement MEDAL with additional data server features. By this means, unclassified data from developmental assets may be integrated into the common operating environment and to enable increases in timeliness of data gathering to be accomplished.

NPS has developed an automated data server (ADS) which links into the accepted input and output channels already active in the Navy's Global Command And Control System (GCCS-M) and MEDAL. We have set up a working stand-alone MEDAL station, received training on its use from SAIC, and demonstrated how data for vehicle positions, contact locations, mine-like contact images, and bathymetry data can be displayed in near to real time. Data gathered during FBE-Hotel included Remus, Morpheus, OEX, and BPAUV vehicle data files with bathymetry, positions, image files and contact locations.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications

KEYWORDS: Autonomous Systems, Robotics, Command and Control, Tactical Decision Aids, Other (Autonomous Systems)

MINE SWEEPING WITH MULTIPLE VEHICLES AND ATTRITION

Anthony J. Healey, Professor
Department of Mechanical Engineering
Sponsor: Coastal Systems Station

OBJECTIVE: This work is aimed at developing a study of sweeping effectiveness for AUV's used as electromagnetic/mechanical minesweepers. The primary focus is on developing a simulation studying the use of multiple vehicles carrying magnetic sweepers through a minefield. As mines explode, some vehicles are lost. By selection of vehicle spacing, the minimum range between vehicles can be maximized, thus reducing the likelihood of collateral damage between vehicles. The key point here is that as vehicles are lost, a supervisor reassigns sweep tracks to remaining vehicles so that area coverage is retained.

SUMMARY: The study of effectiveness was accomplished by developing a computer simulation code. The code is written in "C" and runs on an SGI workstation. The data developed by the simulation is

transferred to Matlab and variables of interest such as vehicle positions, paths, locations of mines exploded, and summary statistics, may be plotted as desired.

A study was completed and detailed in an invited paper to the IEEE CDC Conference, 2001. The details are contained in the Thesis work of LT P. Ludwig. What is shown is that this approach to minesweeping is very encouraging. The sweep rates using multiple (20) vehicles are practically useful with a span of 4 hours. We would like to continue the work in the area of more detailed swimmer guidance laws, Account for mines already sensed that did not detonate (smart mines with ship counters), and, optimize the results.

PUBLICATION:

Healey, A. J., "Application of Formation Control for Multi-Vehicle Robotic Minesweeping," *Proceedings of the IEEE CDC Conference***,** Paper No. CDC01-INV3103.

THESIS DIRECTED:

Ludwig, P. M., "Formation Control for Multi-Vehicle Robotic Minesweeping," Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communication, Other (Autonomous Systems)

KEYWORDS: Autonomous Systems, Robotics, Command and Control, Tactical Decision Aids

MODELING OF FIRE AND SMOKE PROPAGATION IN SHIPBOARD SPACES

Matthew D. Kelleher, Professor
Department of Mechanical Engineering
Sponsor: Naval Sea Systems Command

OBJECTIVE: The objective of this proposed work is to model the propagation of fire and smoke in the shipboard environment. Work has been continuing to investigate the modeling of smoke propagation in shipboard compartments and passageways. It is very important that an understanding of the propagation of fire and smoke in the various shipboard spaces be developed and that some means be developed to apply that understanding to incorporate survivability considerations in the design of future combatants and to the development of fire fighting procedures.

SUMMARY: A commercial code developed by CFD Research Corporation (CFDRC) is being used to model the effects of fire in various shipboard spaces. Modeling of smoke propagation in various spaces representative of DD51 have been modeled. Recently modeling of the live fire experiments performed aboard the Navy's full scale DT&E facility, the ex-USS Shadwell, in 1994 has begun. These experiments were performed to investigate shipboard smoke control using a forced counter-flow air supply. The present modeling study is investigating the effects of open hatches or doors on the propagation of smoke from adjacent spaces.

THESES DIRECTED:

Mehls, M., "Propagation of Fire Generated Smoke in Shipboard Spaces," Masters Thesis, Naval Postgraduate School, March 2000.

Abaya, A. F., "Propagation of Fire Generated Smoke in Shipboard Spaces with Geometric Interferences," Masters Thesis, Naval Postgraduate School, September 2000.

Vegara, B. J., "Propagation of Fire Generated Smoke and Heat Transfer in Shipboard Spaces with a Heat Source," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Fire Propagation, Smoke Spread, Ship Survivability, Damage Control

INVESTIGATION OF THE USE OF ARTIFICIAL NEURAL NETWORKS IN HEAT TRANSFER

Matthew D. Kelleher, Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: The objective of this study is to investigate the feasibility of using artificial neural networks as a method of developing predictive algorithms from complex heat transfer experimental data.

SUMMARY: Experimental heat transfer taken for complex situations which involve several independent length scales such as finned tube banks or for multi-fluid systems is usually very difficult if not impossible to correlate. If algebraic correlations are developed in the standard manner the results are usually accompanied by a high degree of uncertainty. Many times the data can only be presented in tabular or graphical form. Application of such data for design calculations can be very difficult.

This work explores the use of artificial neural networks to develop a predictive algorithm using experimental heat transfer data for a complex situation. The data from a series of experiments investigating the boiling heat transfer from a vertical bank of tubes in refrigerant 114 with variable amounts of oil present has been used to illustrate the process. Both finned and unfinned tubes were investigated. The network was trained with a partial set of the available data. The prediction obtained using the trained network was then compared to the remaining experimental data. The artificial neural network provided an excellent predictive method.

THESIS DIRECTED:

Cronley, T. J., "The Use of Neural Networks as a Method of Correlating Thermal Fluid Data to Provide Useful Information on Thermal Systems," Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Artificial Neural Networks

MODELING AND SIMULATION OF DAMAGE AND CRACKS IN PARTICULATE COMPOSITE MATERIALS: EFFECTS OF HYDROSTATIC PRESSURE

Young W. Kwon, Professor
Department of Mechanical Engineering
Sponsors: Air Force Research Laboratory

OBJECTIVE: This was a continuing research project from past several years during which a numerical modeling and simulation technique, called a multi-level (micro-macro) technique, had been developed and evaluated against experimental results. This year's effort was to study the effect of hydrostatic pressure on damage initiation and growth and to model the effect in the damage mechanics.

SUMMARY: The stress-strain behavior of a particulate composite specimen under hydrostatic pressure was modeled using the multi-scale approach. The approach was developed in the past by the investigator. The damage was described at the micro-level analysis in terms of the respective damage of each constituent material. In the present study, a damage theory was developed based on the two components of strain energy density: dilatational and deviatoric energy densities. The dilatational energy associated with the hydrostatic pressure was assumed to hold back the damage initiation. Using this concept, qualitatively acceptable stress-strain behaviors of the particulate composite were predicted under various levels of the hydrostatic pressure. The predicted results agreed well with the behavior observed in experimental studies.

The initial crack sizes at circular notch tips were predicted and compared to the experimental measurement when there was no hydrostatic pressure. The predicted values compared very well to the test data. When the study included a hydrostatic pressure, the initial crack size did not vary even though the crack formed at a higher applied strain level. This study did not include the pressure penetration into the crack to be applied to the crack faces. This effect needs to be studied in the subsequent study.

PUBLICATIONS:

Kwon, Y.W. and Liu, C.T., "Prediction of Initial Crack Size in Particulate Composites with a Circular Hole," *Mechanics Research Communications*, Vol. 27, No. 4, 2000, pp. 421-428.

Kwon, Y.W. and Eren, H., "Micromechanical Study of Interface Stresses and Failure in Fibrous Composites Using Boundary Element Method," *Polymers and Polymer Composites*, Vol. 8, No. 6, 2000, pp. 369-386.

McDermott, P.M. and Kwon, Y.W., "A Stable Algorithm for Void Growth and Nucleation in Transient, Elasto-plastic Analysis of Plate Bending," *Engineering Computations*, Vol. 17, No. 7, 2000, pp. 857-873.

Kwon, Y.W. and Liu, C.T., "Effect of Particle Distribution on Initial Cracks Forming from Notch Tips of Composites with Hard Particles Embedded in a Soft Matrix," accepted for publication in *Composites, Part B: Engineering.*

Kwon, Y.W. and Craugh, L.E., "Progressive Failure Modeling in Notched Cross-Ply Fibrous Composites," accepted for publication in *Applied Composite Materials.*

Kwon, Y. W. and McDermott, P. M., "Effects of Void Growth and Nucleation on Plastic Deformation of Plates Subjected to Fluid-Structure Interaction," submitted for publication.

Kwon, Y.W. and Altekin, A., "Multi-level, Micro-Macro Approach for Analysis of Woven Fabric Composites," submitted for publication.

Kwon, Y. W. and Liu, C. T., "Modeling of Hydrostatic Pressure Effect on Progressive Damage in Particulate Composites," *Recent Advances in Solids and Structures -2000,* ASME PVP Vol. 415, 2000, pp. 65-72.

PRESENTATIONS:

Kwon, Y.W., Eren, H., and Liu, C.T., "Study of Fiber/Matrix Interface Stresses and Failure Using Boundary Element Method," International Congress on Advanced Materials, their Processes and Applications, September 2000.

Kwon, Y. W., "Multilevel Approach for Failure in Woven Fabric Composites," International Congress on Advanced Materials, their Processes and Applications, September 2000.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: Particle Reinforced Composite, Solid Rocket Propellant, Damage and Crack, Modeling and Simulation, Initial Crack Size, Hydrostatic Pressure

COMPUTER MODELING AND SIMULATION OF THE HUMAN THORAX UNDER BULLET IMPACT

Young W. Kwon, Professor
Department of Mechanical Engineering
Sponsor: United States Army Soldier and Biological Chemical Command
Armed Forces Institute of Pathology

OBJECTIVE: This was a continuing research project from the previous years. This year's effort was to model the human thorax with protective body armors hit by high-speed bullets in order to evaluate potential injury.

SUMMARY: The finite element analysis model was developed for the human thorax of skeleton including ribs, sternum, vertebrae, vertebral discs, facet joints, costal cartilages, muscle, etc. Two different body armors, one with a kevlar vest and the other with a vest and armor plate, were also modeled. The results of the computer model were compared to the experimental data obtained with human cadavers with body armors hit by bullets. In the model, the measured speed of the bullet was used. The comparison of accelerations in the sternums and spines were very good, especially the sternum accelerations for two different body armors. Those results provided reliability of the developed computer model. The next step is to implement major internal organs for their potential injury evaluation.

PUBLICATIONS:

Kwon, Y. W., Jolly, J. E., and Hughes, T. A., "Ballistic Impact Analysis of the Human Thorax with a Protective Body Armor," *Recent Advances in Solids and Structures -2000,* ASME PVP Vol. 415, 2000, pp. 11-15.

Jolly, J. E. and Kwon, Y. W., "Computer Modeling and Simulation of Bullet Impact to the Human Thorax," Naval Postgraduate School Technical Report, NPS-ME-00-002, June 2000.

Kwon, Y. W., Jolly, J. E., and Hughes, T. A., "Modeling of Dynamic Response of the Human Thorax with Protective Body Armors under Projectile Impact," submitted for publication.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Finite Element Method, Human Thorax Model, Body Armors, Dynamic Response

GLOBAL DAMAGE DETECTION IN COMPOSITE STRUCTURES

Young W. Kwon, Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: This project was to develop a technique for damage detection and identification in sandwich composite structures containing interfacial cracks.

SUMMARY: The project was about damage detection and identification in sandwich structures containing embedded interface cracks. A global damage detection technique using dynamic characteristics was used in numerical experiments. The study models interface cracks as they were without artificially smearing either material or geometric properties. The study showed that proper modeling of cracks with contact elements was important for representation of the behavior of cracks. In addition, smearing geometric or material properties to represent such interface cracks was found to be generally unacceptable. Measuring local dynamic strains (stresses) shed lights for hidden damage detection and identification of locations.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEYWORDS: Damage Detection, Sandwich Structures, Embedded Cracks, Interface Cracks, Finite Element Analysis

PROCESSING, GRAIN BOUNDARIES AND SUPERPLASTICITY IN ALUMINUM

Terry R. McNelley, Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: The goal of this program is to determine the mechanisms of grain boundary development during deformation processing, the mechanisms by which deformation microstructures may transform to a fine-grained, superplastic state, and the deformation behavior of such microstructures.

SUMMARY: Our current understanding of microstructural refinement by deformation and recyrstallization is largely empirical and so the ability to predict and then produce refined microstructures for various purposes, such as superplasicity, is severely limited for aluminum and its alloys. Recently developed computer-aided electron microscopy diffraction analysis methods have been applied to the investigation of the mechanisms of grain boundary development during deformation processing of several aluminum alloys. Materials have been examined following various thermomechanical processing schedules and deformation histories. Aluminum alloy 5083 transforms to a refined, superplastic microstructure via a primary (discontinuous) recrystallization reaction involving the formation and migration of high-angle grain boundaries while Supral 2004 and Al-5Ca-5Zn materials transform by a continuous process. These different transformation processes may be distinguished by distinct differences in grain boundary characteristics and deformation behaviors.

PUBLICATIONS:

McNelley, T.R. and Pérez-Prado, M.T., "A Computer Simulation of Grain Boundary Character in a Superplastic Aluminum Alloy," in *Symposium Proceedings: Superplasticity - Current Status and Future Potential*, Vol. 601 (P.B. Berbon, M.Z. Berbon, T. Sakuma and T. G. Langdon, eds.), Materials Research Society, Pittsburgh, PA, 2000, pp. 3-14.

McNelley, T.R., "A Processing, Recrystallization and Superplasticity in Aluminum Alloys," in *Deformation, Processing and Properties of Structural Materials, Symposium in Honor of Oleg D. Sherby*, E.M Taleff, C.K. Syn and D.R. Lesuer, eds., TMS, Warrendale, PA, 2000, pp. 339-53.

Pérez-Prado, M.T., McNelley, T.R., González-Doncel, G., and Ruano, O.A., "A Texture, Grain Boundaries and Deformation of Superplastic Aluminum Alloys," in *Proceedings of ICSAM 2000, International Conference on Superplasticity in Advanced Materials*, N. Chandra, ed., in press.

McNelley, T.R., "A Continuous Recrystallization in Grain Boundaries in a Superplastic Aluminum Alloy," Chapter 22 in *Electron Backscatter Diffraction in Materials Science*, A.J. Schwartz, M. Kumar and B.L. Adams, eds., Kluwer Academic/Plenum Publishers, New York, 2000, pp. 277-90.

Eddahbi, M., McNelley, T.R., and Ruano, O.A., "A Characterization During Superplastic Deformation of an Al-6%Cu-0.4%Zr Alloy," *Metallurgical and Materials Transactions*, in press.

Pérez-Prado, M.T., Swisher, D.L., and McNelley, T.R., "A Deformation Banding, Grain Boundaries and Continuous Recrystallization in a Superplastic Aluminum Alloy," in *Proceedings of THERMEC 2000, International Conference on Processing and Manufacturing of Advanced Materials*, T. Chandra, ed., in press.

Pérez-Prado, M.T., González-Doncel, G., Ruano, O.A., and McNelley, T.R., "A Texture Analysis of the Transition from Slip to Grain Boundary Sliding in a Discontinuously Recrystallized Superplastic Aluminum Alloy," accepted for publication in *Acta Mater.*

PRESENTATIONS:

McNelley, T.R. and Pérez-Prado, M.T., "A Computer Simulation of Grain Boundary Character in a Superplastic Aluminum Alloy," Symposium HH: Advances in Superplasticity and Superplastic Forming, 1999 Fall MRS Meeting, Boston, MA, 29 November 1999.

McNelley, T.R., "A Processing, Recrystallization and Superplasticity in Aluminum Alloys," Symposium in Honor of Oleg D. Sherby, 2000 Annual TMS Meeting, Nashville, TN, 15 March 2000.

Pérez-Prado, M.T., McNelley, T.R., González-Doncel, G., and Ruano, O.A., "A Texture, Grain Boundaries and Deformation of Superplastic Aluminum Alloys," ICSAM 2000, International Conference on Superplasticity in Advanced Materials, ICSAM 2000, Orlando, FL, 6 August 2000.

McNelley, T.R.,"A Continuous Recrystallization in Grain Boundaries in a Superplastic Aluminum Alloy," Symposium on Electron Backscatter Diffraction in Materials Science, 2000 Fall Meeting of ASM and TMS, St. Louis, MO, 18 October 2000.

Pérez-Prado, M.T., Swisher, D.L., and McNelley, T.R., "A Deformation Banding, Grain Boundaries and Continuous Recrystallization in a Superplastic Aluminum Alloy," THERMEC 2000, International Conference on Processing and Manufacturing of Advanced Materials, THERMEC 2000, Las Vegas, NV, 5 December 2000.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEYWORDS: Aluminum, Superplasticity, Recrystallization, Grain Boundaries, Thermo-mechanical Processing

ULTRA-FINE AND NANO-GRAIN MICROSTRUCTURES BY SEVERE PLASTIC DEFORMATION

Terry R. McNelley, Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: The goal of this program is to determine mechanisms by which ultra-fine grain structures form in severely deformed materials, such as those processed by equi-channel angular (ECA) pressing

SUMMARY: Ultra-fine grain sizes in the sub-micrometer or even nanometer range can be achieved in metallic materials by imposing extremely large plastic strains during deformation processing. Such grain refinement will result in drastic improvements in strength/toughness combinations for structural applications as well as in improved ductility during elevated temperature forming. Methods such as ECA pressing are required in order to impart stains large enough to produce such refinement. ECA pressing is accomplished by pressing a billet of material through a die having two channels, of equal cross section, that intersect at an angle. Such a billet experiences simple shear without change in cross-sectional area and so the process is amenable to repetition. Billet rotation between successive pressing operations allows the shear plane orientation to be changed in order to achieve further control of microstructural refinement. The characteristics of the grain structures and, especially, the nature of the grain boundaries produced by such processing have remained in question. However, grain-to-grain misorientations may be readily determined by newly developed computer-aided electron backscatter pattern (EBSP) analysis methods.

PUBLICATIONS:

McNelley, T.R., "A The Application of EBSD Methods to Evaluate Grain Boundary Character of Fine-Grained Pure Aluminum," in *Ultra-Fine Grained Materials and Processing*, R. Mishra, ed., TMS, Warrendale, PA, 2000, pp. 339-53.

Terhune, S.D., Oh-ishi, K., Horita, Z., Langdon, T.G., and McNelley, T.R., "An Investigation of Grain Boundary Character Evolution during ECA Pressing of Pure Aluminum," submitted to *Metallurgical and Materials Transactions.*

PRESENTATION:

McNelley, T.R., "A The Application of EBSD Methods to Evaluate Grain Boundary Character of Fine-Grained Pure Aluminum," Symposium on Ultra-Fine Grained Materials and Processing, 2000 Annual TMS Meeting, Nashville, TN, 14 March 2000.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEYWORDS: Aluminum, Grain Refinement, Nano-Grain Materials, Recrystallization, Grain Boundaries, Materials Processing

REDUCING RAMP STRESS LEVELS VIA SEMI-ACTIVE DAMPING

Fotis A. Papoulias, Associate Professor
Joshua H. Gordis, Associate Professor
Department of Mechanical Engineering
Funding: Naval Surface Warfare Center-Carderock

OBJECTIVE: The current ramp design used in roll-on roll-off operations has been determined to be structurally inadequate in sea state 3. The overall objective of this continuing project is to determine the isolation properties that are required in order to reduce ramp stress levels below the allowable for worst-case loading.

SUMMARY: A mathematical model describing the fundamental physics of a ship/ramp/barge system, including a passive isolator, was developed. The model properly accounts for hydrodynamic proximity effects and structural coupling between the bodies. Preliminary parametric studies, utilizing a standard second order model for the frequency response properties of the connecting body, of the response amplitude operator of the ramp motion were performed for varying wave directions and isolator stiffness and damping. These were utilized for random wave analysis in standard fully developed seas. The results indicated that rational selection of isolator properties could result in significant reduction of motions and stress levels in the connecting ramp. Current efforts include incorporation of actual FEM results coupled with the existing hydrodynamic prediction models.

PUBLICATION:

Gordis, J.H., Papoulias, F. and Leban, F., "Validation of Frequency Response Synthesis for Large-Scale Structural Isolation Design," *Proceedings of the 71st Shock and Vibration Symposium*, Arlington, VA, 6-9 November 2000.

THESIS DIRECTED:

Konstantinou, D.S., "Random Wave Analysis of Ship/Ramp/Barge Response," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ships and Watercraft

KEYWORDS: Frequency Response, Seakeeping, RORO Operations, Vibration Isolation

FREQUENCY RESPONSE ANALYSIS OF THE T-ACS SEAKEEPING EXPERIMENTS

Fotis A. Papoulias, Associate Professor
Department of Mechanical Engineering
Funding: Naval Surface Warfare Center-Carderock

OBJECTIVE: The objective of this project was to perform frequency response analysis of the DTMB runs 1-503 and NRL runs 1-217 of the T-ACS seakeeping experiments.

SUMMARY: Trial runs of a 1:24 scale model crane ship were conducted in the David Taylor Model Basin. The model's responses to regular waves under various ship configurations, crane configurations, sea states and ship headings relative to the incoming waves were recorded. This project analyzed the frequency response characteristics of the model and generated the model and full-scale spectra and Response Amplitude Operators, or RAOs. Several techniques of data filtering were utilized and compared. Accurate generation of full-scale RAOs enables future prediction, using the principle of linear superposition, of ship motions in an irregular sea. Such predictions can be compared to actual, full-scale trial runs that are currently being conducted.

THESIS DIRECTED:

Elvis, G.G., "Frequency Response Analysis of T-ACS Experimental Data," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ships and Watercraft

KEYWORDS: Frequency Response, Seakeeping

VORTEX BREAKDOWN IN TURBULENT SWIRLING FLOWS

T. Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: National Science Foundation and Naval Postgraduate School

OBJECTIVE: Vortex breakdown is the transformation of a slender vortex into three-dimensional forms. Where, how, and under what circumstances does this transformation occur in *viscous* vertical flows constitute the essence of the breakdown problem. Neither a stagnation point, nor a region of reversed flow, nor the bridging of laminar–turbulent states is necessary. Trailing vortices, swirling flows in pipes, vortical flows above sweptback wings at large angles-of-attack, flows in closed containers with a rotating lid, and columnar vortices in atmosphere may experience breakdown. Where, how, and under what circumstances does the breakdown occur in *viscous* vortical flows constitute the essence of the investigation.

SUMMARY: The definition of the spectral characteristics of the conical region is the subject of the ongoing investigation. The mean velocities and turbulence intensities were measured in forward-scattering mode with a three-component Laser Doppler Anemometer. The results refute the conjectures that the circumstances of breakdown are insensitive to the Reynolds number and the local turbulence properties. These two factors have a strong influence on the evolution of the flow. Of all the known forms, the spiral emerges as the most fundamental breakdown form. All other forms may be regarded as transient states affected by various types of instabilities. At very high Reynolds numbers the breakdown acquires forms and characteristics never seen before: Extremely high rates of revolution, onset of core-bifurcation or core-trifurcation, intense nonisotropic turbulence, and a conical shape.

PUBLICATION:

Novak, F. and Sarpkaya, T., "Vortex Breakdown at High Reynolds Numbers," *American Institute of Aeronautics and Astronautics Journal,* Vol. 38, No. 5, May 2000, pp. 1671-1679.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles

KEYWORDS: Vortex Breakdown, Vorticity, Swirling Flow

DEVELOPMENT OF A NEW VORTEX-DECAY MODEL IN THE ATMOSPHERE

T. Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: National Aeronautics and Space Administration-Langley

OBJECTIVE: The purpose of this continuing investigation is (a) to develop a new vortex decay model for the prediction of the descent of aircraft trailing vortices subjected to realistic environmental conditions (stratification, turbulence, cross wind, headwind, shear effects, and ground effect), and (b) to apply the model to field data obtained with Lidar in Memphis and Dallas–Fort Worth airports.

SUMMARY: A robust and relatively simple physics-based vortex decay model has been devised. It does not violate any hydrodynamical principles, has only one model constant, uses the turbulence eddy dissipation rate in conjunction with a theoretical model (as verified by experiments and numerical simulations), and it requires no cumbersome algorithms to account for the ground effects. Acquisition of better and more detailed field data (vortex velocities and positions; wind, shear and their gradients; better temperature, humidity, and eddy dissipation profiles), the quantification of the consequences of unstable stratification, and the optimization of the new model parameters constitute the essence of this continuing research of vital international importance.

PUBLICATIONS:

Sarpkaya, T., "New Model for Vortex Decay in the Atmosphere," *Journal of Aircraft (AIAA),* Vol. 37, No. 1, January/February 2000, pp. 53-61.

Sarpkaya, T., "Resistance in Unsteady Flow: Search for an In-Line Force Model," *International Journal of Offshore and Polar Engineering,* Vol. 10, No. 4, December 2000, pp. 1053-5381.

Sarpkaya, T., Robins, R.E., and Delisi, D.P., "Wake-Vortex Eddy Dissipation Model Predictions Compared with Observations," *Journal of Aircraft (AIAA),* Vol. 38, No. 4, July-August 2000, pp. 234-240.

OTHER:

The model has now been incorporated into NASA's AVOSS program for the management of aircraft landings at large airports (JFK, Memphis, DFW, New Orleans).

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Trailing Vortices, Aircraft Wakes, Wake Hazard

SPRAY FORMATION AT THE FREE SURFACE OF LIQUID WALL JETS

T. Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: This continuing basic research is an experimental investigation of the ligament and drop formation at the free surface of liquid wall jets, flowing over smooth and sand-roughened plates towards the understanding of the physics of droplet formation, in general, and of the spray formation on bow-sheets, in particular.

SUMMARY: Measurements were made with several high-speed imagers, a pulsating laser, and a Digital Particle Image Velocimeter (DPIV) system and analyzed through the use of appropriate software. The wall-jet Reynolds number ranged from 2.4×10^4 to 4×10^4, the Froude number from 15 to 30, and the Weber number from 1,500 to 3,000. The characteristics of the ligament forest and droplets were determined from the digitized images.

PUBLICATIONS:

Sarpkaya, T. and Merrill, G., "Spray Formation at the Free Surface of Liquid Wall Jets," *Naval Hydrodynamics*, Vol. 22, October 1999, pp. 145-154.

Sarpkaya, T. and Vaidyanathan, R., "Spray Generation from Free and Half-Free Jets," AIAA 2000-0817, January 2000, *AIAA Journal.*

Sarpkaya, T., "Characterization of the Free Surface Structuers on High-Speed Liquid Jets," *Proceedings of the ICLASS (International Congress on Liquid Atomization and Spray Systems)*, Pasadena, CA, July 2000, pp. 1-8.

Sarkaya, T. and Merrill, C.F. "High Speed Laser-PIV Imaging for the Eulerian-Lagrangian Measurement and Visualization of Spray on Wall-Bounded Jets," *Proceedings of the ICLASS (Ingernational Congress on Liquid Atomization and Spray Systems)*, Pasadena, CA, July 2000, pp. 9-17.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ships and Watercraft

KEYWORDS: Hydrodynamics, Drop Formation, Spray

A UNIVERSAL FORCE MODEL FOR BLUFF BODIES IN UNSTEADY FLOW

T. Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: Office of Naval Research

OBJECTIVE: A combined analytical, numerical, and physical analysis has been carried out to devise a physics-based model for the prediction of flow-induced unsteady forces on bluff bodies immersed in time-dependent flows. The new model, based on a sounder scientific rational is superior to the well-known Morison equation and offers greater universality and higher engineering reliability, particularly in the so-called inertia/drag regime.

SUMMARY: Over 3,000 digital force-time-data files have been evaluated during the course of the investigation in order to evaluate the residue for each combination of the Keulegan-Carpenter number Kc, Frequency parameter b, the Reynolds number Re, and the relative roughness k_S/D. It has been shown that the viscous drag force and the inviscid inertia force do not operate independently and it is not possible to divide the measured time-dependent force into an inviscid inertial force and a viscous drag force. The modification proposed herein to the existing Morison equation through the addition of a third term offers greater universality and higher engineering reliability, particularly in the so-called drag–inertia regime.

PUBLICATION:

Sarpkaya, T., "Resistance in Unsteady Flow: Search for an In-Line Force Model," *International Journal of Offshore and Polar Engineering*, Vol. 10, No. 4, December 2000, pp. 1053-5381.

THESIS DIRECTED:

Osgood, D. B., "Flow About Perforated Bodies," Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Bluff Body, Resistance, Unsteady Flows, Vorticity

SHOCK AND VIBRATION ANALYSIS IN SUPPORT OF DDG-51 CLASS SHOCK FOLLOW-ON ACTIONS

Young S. Shin, Professor
Department of Mechanical Engineering
Sponsor: Naval Sea Systems Command and Naval Postgraduate School

OBJECTIVE: To perform shock and vibration analysis in support of DDG-51 Class shock follow-on actions including DDG-51 Flight IIA ship shock analysis to predict dynamic responses of ship system and subsystem structures to underwater explosions.

SUMMARY: This task is a part of team project consisting of NAVSEA, NSWC, General Dynamics, Weindlinger Associates, Gibs & Cox, and NPS. The CY2000 was final year to complete the project. I was responsible to perform 3-D surface ship shock modeling and simulation of USS John Paul Jones, DDG53. The task includes investigating whether the ship shock modeling and simulation can predict the dynamic transient responses of ship system and subsystem structures accurately. The ship shock trial data of DDG53 conducted in June 1994 were used for data comparison. The analysis takes into account of the effects of the fluid-ship structure interaction and cavitation effects on a surface ship model (DDG-53) due to a large scale underwater explosion. The simulation results were favorably compared well with those of ship shock trial data. This analysis was a first attempt to conduct 3-D full ship shock simulation of navy ship and the results was successful.

PUBLICATIONS:

Shin, Y.S., "Total Ship Shock Modeling and Simulation Using LS-DYNA/USA," *Proceedings of LS-DYNA Users Conference 2000,* Osaka, Japan, 3-4 October 2000.

Malone, P.E. and Shin, Y.S., "Sensitivity Analysis of Coupled Fluid Volume to Ship Shock Simulation," *Proceedings of 71st Shock and Vibration Symposium,* Crystal City, VA, 6-9 November 2000.

Shin, Y.S., "Surface Ship Shock Simulation Subjected to Underwater Explosion," *Proceedings of NAV2000 Conference*, Venice, Italy, 20-22 September 2000.

PRESENTATIONS:

Shin, Y.S., "Total Ship Shock Modeling and Simulation Using LS-DYNA/USA," LS-DYNA Users Conference 2000, Osaka, Japan, 3-4 October 2000.

Malone, P.E. and Shin, Y.S., "Sensitivity Analysis of Coupled Fluid Volume to Ship Shock Simulation," 71st Shock and Vibration Symposium, Arlington, VA, 6-9 November 2000.

Shin, Y.S., "Overview of Underwater Shock and DDAM," 3-Hour Tutorial presented at the 71st Shock and Vibration Symposium, Arlington, VA, 6-9 November 2000.

THESES DIRECTED:

Trevino, T., "Applications of Arbitrary Lagrangian-Eulerian (ALE) Analysis Approach to Underwater and Air Explosion Problems," Masters Thesis, Naval Postgraduate School, September 2000.

Malone, P.E., "Surface Ship Shock Modeling and Simulation: Extended Investigation," Masters Thesis, Naval Postgraduate School, December 2000.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles – Ships and Watercraft

KEYWORDS: ALE Analysis, Underwater Explosion, Cavitation, Fluid-structure Interaction

FRAGMENTATION AND DETONATION OF ANTIPERSONNEL MINE AND SURVIVABILITY OF SENSORS IN THE GRIZZLY

Young S. Shin, Professor
Department of Mechanical Engineering
Naval Postgraduate School
Sponsor: U.S. Army Tank Automotive Command and Naval Postgraduate School

OBJECTIVE: The Grizzly has various sensors including control sensors, laser systems, hydraulic lines, wires and various cameras mounted on the Grizzly armor hull, which is exposed to various types of landmine detonation. The objective is to study the detonation and fragmentation process of mine such as OMZ-72 antipersonnel mine and to extend the study on effect of shock wave and fragmentation to the survivability of sensors, laser systems, cameras, wires and hydraulic lines exposed to the threat. Based on the results investigated, NPS will provide design guidance on protecting sensors, laser systems, wires and hydraulic lines, etc., from the threat. The pop-up anti-personnel mines such as the OZM-72 has unique and of interesting features about its horizontal dispersion of fragmentation. The project results will provide design guidance from a better understanding of the threat.

SUMMARY: The Grizzly meets a long-standing requirement for a vehicle that can defeat complex obstacles and clear mines on the battlefield. Minefields, barb wire entanglements, tank ditches and other fortifications are often used in combination to divert, deny and paralyze the forward momentum of mechanized forces during offensive operations. In addition, the Grizzly has a full camera vision systems installed. The author, post-doctorates and graduate students in Naval Postgraduate School have been involved in research and development on shock testing, modeling and simulation of detonation and explosion processes for the span of last twenty years. We also conducted the studies on armor base plate responses subjected antitank landmine for various material types. The response types include shock wave response, impact, penetration and perforation.

THESIS DIRECTED:

Trevino, T., "Applications of Arbitrary Lagrangian-Eulerian (ALE) Analysis Approach to Underwater and Air Explosion Problems," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: ALE Analysis, Fragmentation and Detonation, Land Mine

IMPACT ANALYSIS AND ACTIVE VIBRATION DAMPING ON ORBITAL VEHICLES

Young S. Shin, Professor
Department of Mechanical Engineering
Sponsor: National Aeronautics and Space Administration-Dryden

OBJECTIVE: To develop a method to determine the location, force, and orientation of an impact on a space truss using a minimal distributed sensor grid. Also achieve improved active control of vibrations induced in the truss by installed equipment operating at a constant frequency. The active control is to be achieved using piezoelectric elements installed as truss members and should be able to control the vibration at multiple nodes and sensitive to various axis without relocating the active elements. A FEM of the truss, generated using ANSYS, is to be used to assess the ability to model the implementation of the control algorithm and will be compared to the actual experimental results.

SUMMARY: This task is in collaboration with both the Aeronautical Engineering and Electrical Engineering curriculums using facilities located in H-022. The NPS Space Truss is used to simulate a generic orbital platform and is mounted on a vibration isolation table. The truss also has potential to be scaled up to a larger application such as ALPHA, the International Space Station. The ability to validate the application of the control method using a computer model has even broader potential for future applications, with the ability to be applied to any valid FEM. The impact analysis motivation is to allow remote monitoring of systems that are subjected to the potential impacts of micrometeorites. This includes all orbital systems, but is specifically tuned in this research to truss applications. The potential application of similar technology to more conventional aircraft is also of interest to the sponsor.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Space Systems)

KEYWORDS: Space Truss, Active Vibration Damping, Piezoelectric Elements, Impact Analysis, ANSYS, FEM Simulation of Active Control Method